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ELECTROSTATIC PRECIPITATION OF PESTICIDAL DUSTS, AN OUTLINE OF RESEARCH AND LITERATURE

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Plant pests are of great concern to the producer (and consumer) of food. This is exemplified by the fact that plant insects and diseases reduced the annual income of United States farmers more than three billion dollars during the period 1942 to 1951. 2/ Furthermore, disease and insect damage lowers quality and decreases the storage life of nearly all farm products.

In 1952, farmers spent 193 million dollars applying control measures to 29 million acres of crops. 3/ The cost of control has undoubtedly risen in more recent years.

The efficiency (Efficiency: percentage of total pesticide material delivered by the equipment which adheres to plant surfaces and becomes useful in pest control) of existing pesticidal dusting equipment and procedures is relatively low, despite the fact that they are as well designed and developed as is presently possible. It would be difficult to give an over-all efficiency estimate, since such factors as equipment, crops, meteorological conditions, pesticide material, and method of operation introduce great variability. Bowen, Carleton, and Hebblethwaite (6: 1952) 4/ and Ban (2: 1955), however, report for carefully adjusted and operated conventional dusting equipment efficiencies of 10 to 20 percent.

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2/ Fracker, S.B., and others. Losses in Agriculture. United States Department of Agriculture, June 1954, 190 pp.

3/ Smith, Richard K., and others. Agricultural Statistics 1954. United States Department of Agriculture, 1954, 607 pp.

4/ Numbers and years occurring together within parentheses refer to items and publication dates in "References," p.4.

Improved efficiency of application would not only reduce control cost but would provide better control. The resulting decrease in the quantity of waste pesticide would reduce the health hazard to the farmer and the surrounding community.

The literature indicates that nearly all efforts to improve the efficiency of dust pesticide applications have involved the use of electrostatic forces. Briefly, this consists of the placement of electrical charges (positive or negative electrical sign) upon the particles, with subsequent dependence upon an electric field (the precipitating field) to drive the particles onto the plants. Various particle-charging schemes have been tried: e.g., friction; corona-discharge dust nozzles; and charging in the precipitating field itself (the existence of an adequate supply of ions in the precipitating field is assumed). The precipitating fields have been derived from (1) the "natural" electrical potential gradient which exists between the charged dust cloud and the electrically grounded plant or (2) an "artificially" impressed field (produced, e.g., by a high-voltage conducting grid placed in the vicinity of the plants) in addition to the "natural" gradient.

Various Approaches to the Electrostatic Precipitation Problem

The existence of friction-charging effects, which accompany passage of dust through conventional machines,has been appreciated for some time by people working with the equipment. MacLeod and Smith (24: 1943) carried on investigations to determine the magnitudes and signs of dust charges as affected by the pesticide material. More recently, Kunkel and Hansen (19: 1950) and Kunkel (17: 1950; 18: 1950) have conducted rather extensive studies of aerosol particle electrification and behavior.

Probably the first systematic attempt to utilize electrostatic forces for pesticidal dust precipitation was by Hampe (14: 1947) of France, who based his work largely on the findings of Pauthenier and Moreau-Hanot (25: 1932). Hampe used the method of particle charging in an artificially impressed precipitating field. The required high direct-current potential was derived from an electrostatic generator. Hampe's results are not available in detail, but he claims application efficiencies as high as 75 percent. Felici (13: 1953) indicates, however, that the method did not succeed economically owing to the unwillingness of the French farmers to buy the relatively expensive apparatus at a time when their government was maintaining low prices on pesticide materials. Apparently patent problems may have prevented introduction of this particular method into the United States.

Yadoff (30: 1946; 31: 1946) of France attempted to eliminate the need for a high-potential source by friction-charging the dust particles in a supersonic air jet and depending upon the cloud potential for precipitation. Yadoff's process was subjected to testing in the United States and was found to be adversely affected by higher atmospheric

humidities. Also, improvement in charging effect over that encountered in ordinary conventional machines was insufficient to give support to the more complicated Yadoff process.

Investigations of a method which involved use of a corona-type dust charging nozzle and the "natural" precipitating gradient were undertaken at Michigan State University from 1950 to 1952 by Bowen (4: 1951), Hebblethwaite (15: 1952), and Carleton (Bowen, Carleton, and Hebblethwaite: 6: 1952). Some success was realized with the method (in some cases efficiency was approximately double that of conventional methods), but inconsistent results indicated that the method was unsuitable for practical use at the time, and that a definite need existed for development of basic theoretical and experimental information. Accordingly, the research effort was diverted to investigating methods of qualitatively and quantitatively evaluating dust deposits, and to studies of (1) corona discharges as related to particle charging, (2) atmospheric-humidity influences, (3) plant-surface effects, (4) dust-cloud potential distributions, (5) particle-size distributions, and (6) particle charging phenomena, as reported by Bowen (5: 1953), Brittain (9: 1954), Brittain, Brazee, and Carleton (10: 1955), Ban and Carleton (3: 1955), Splinter (28: 1955), Ban (2: 1955), Brittain and Carleton (11: 1957), and Brazee (7: 1953; 8: 1957). The Michigan State University project is inactive at this writing.

An important finding which came out of the Michigan State University work is that despite the lower efficiency of the naturally charged cloud gradient, it produced more homogeneous distributions of pesticide on plant surfaces than the strong, artificially impressed fields, except for leaves and stems in the inner regions of plants.

Status of the Problem at the Close of 1957

Although some success has been realized with the use of electrostatic forces, it seems that considerable developmental research remains to be done before a useful practical process is established. A need for basic research in the fundamental physics of aerosol behavior has been indicated by past research efforts.

A theory is needed whereby all significant forces and phenomena, which affect aerosol, behavior can be dealt with as concisely as possible. At our present state of knowledge of (1) inertial, (2) viscous, (3) gravitational, (4) electric, (5) magnetic, and (6) thermal gradient forces, the pertinent phenomena of (1) static electrification, (2) gaseous electric discharges, and (3) problems of particle adherence to depositing surfaces seem to merit consideration.

A Summary of Publications Related to Electrostatic Precipitation of Dust

The following is a list of references related to pesticidal dust precipitation. Although some references are not directly concerned with pesticidal dust precipitation, their importance to the subject warrants their insertion.

Reprints of articles listed which appeared in Agricultural Engineering should be obtainable from:

American Society of Agricultural Engineers
420 Main Street
St. Joseph, Mich.,

or:

Department of Agricultural Engineering
Michigan State University
East Lansing, Mich.

Copies of the unpublished Ph.D. theses listed should be obtainable from:

University Microfilms
313 North First Street
Ann Arbor, Mich.

Copies of unpublished M.S. theses listed may be obtained on an interlibrary loan by having your local librarian contact the Michigan State University Librarian at the following address:

Office of the Librarian
Michigan State University Library
East Lansing, Mich.

Copies of the Institute of Physics publication: Static Electrification, may be purchased from:

The Institute of Physics
47 Belgrave Square
London, S.W. 1, England

References

1. Ballu, Tony.
Poudrage Electrique des Vegetaux par le Procede de Yadoff.
Report to the Academi d'Agriculture de France, March 4, 1946.

This report describes the Yadoff frictional dust-charging process in fair detail. Some problems of dust precipitation on plants are considered. A major part of the report consists of a communication from Yadoff, delivered by Ballu. The work is in French.

2. Ban, Nguyen Tu.
Contributions to Electrostatic Dusting: 1. Application of Polarography to Dust Deposit Evaluation, 2. Effect of Ionized Current Intensities and Effect of Shielding on Dust Deposition. Unpublished M.S. thesis. Michigan State University, 1955, 92 numbered leaves.

This thesis deals with the development and use of procedures for the determination of the quantity and uniformity of dust applications upon plant leaves. Also considered are the effects of current intensity and shielding upon the deposition of dust.

3. Ban, Nguyen Tu, and Carleton, Walter M.
Evaluation of Dust Deposits by Polarography.
Agricultural Engineering 36 (December 1955), pp. 803-905.

This journal article deals with the evaluation of dust deposit by polarography covered by the first portion of Reference No. 2.

4. Bowen, Henry D.
Electrostatic Precipitation of Dusts for Agricultural Applications. Unpublished M.S. thesis. Michigan State University, 1951, 76 numbered leaves.

This thesis covers the early research work at Michigan State University. Laboratory experiments showed that electrically charged dust particles increased the amount of dust deposited on plant foliage. The theory of particle charging is discussed in detail.

5. Bowen, Henry D.
Electric and Inertial Forces in Pesticide Application. Unpublished Ph.D. thesis. Michigan State University, 1953, 130 numbered leaves.

This thesis covers the development of basic information concerning the effect of electric, inertial, and gravitational forces upon charged particles. The results indicate that electric forces are generally small compared to inertial forces and are comparable in magnitude to gravitational forces for uniform charge distributions. The electric forces developed within a plant region depend both on the charge density and the thickness of the cloud blanket near the depositing surface.

6. Bowen, Henry D., Carleton, Walter M., and Hebblethwaite, Peter.
Application of Electrostatic Charging to the Deposition of Insecticides and Fungicides on Plant Surfaces.
Agricultural Engineering 33 (June 1952), pp. 347-350.

This journal article covers parts of Reference No. 4 and presents the general theory of electrostatic precipitation of dust upon plant surfaces.

7. Brazee, Ross D.
Deposition Evaluation for Agricultural Dusting Research.
Unpublished M.S. thesis. Michigan State University, 1953,
97 numbered leaves.

This thesis considers and compares various methods of evaluating dust deposits. A copper determination method for field use is discussed.

8. Brazee, Ross D.
Some Basic Measurements for Analysis of Electrostatic Dust Precipitation.
Unpublished Ph.D. thesis. Michigan State University, 1957,
81 numbered leaves.

This thesis discusses the corona discharge (in air) between concentric conducting cylinders, the mathematical description of dust-particle size distributions, and theoretical prediction and experimental measurement of electrical charges on dust. An example of mathematical analysis of dust precipitation in a cylindrical electric field is given.

9. Brittain, Robert W.
The Effect of Plant Surfaces on Pesticidal Dust Deposition.
Unpublished M.S. thesis. Michigan State University, 1954,
130 numbered leaves.

This thesis describes studies of the manner in which plant surfaces affect the deposition of pesticidal dust. A number of surfaces were dusted under controlled conditions in the laboratory and the quantity of dust deposited was evaluated. These surfaces included aluminum; artificial leaves; and bean, tomato, and lettuce leaves.

10. Brittain, Robert W., Brazee, Ross D., and Carleton, Walter M.
Evaluating Dusting and Spraying Efficiency.
Agricultural Engineering 36 (May 1955), pp. 319-320-323.

This journal article discusses the use of the copper titrimetric technique for evaluating the quantity of dust applied to plant surfaces.

11. Brittain, Robert W., and Carleton, Walter M.
How Surfaces Affect Pesticidal Dust Deposition.
Agricultural Engineering 38 (January 1957), pp. 22-25, 31.

This journal article discusses the results obtained in the study described in Reference No. 9.

12. Dallavalle, J. M.
Micromeritics, the Technology of Fine Particles.
Pitman Publishing Corp., New York, 2d. ed., 1948, 555 pp.

A great wealth of material, ranging from particle sizing to the dynamic and precipitation characteristics of fine particles, is contained in this work. An extensive bibliography is included.

13. Felici, Noel J.
Ten Years of Research on Electrostatics at the University of Grenoble, 1942-1952. British Journal of Applied Physics, Supplement No. 2: Static Electrification: A Symposium held by the Institute of Physics in London on 25, 26, and 27 March 1953.
The Institute of Physics, London, 1953, pp. 62-67.

The main concern of this paper is research in the development of electrostatic generators. Some reference is given to their use in electrostatic precipitation of pesticidal dusts.

14. Hampe, Pierre.
Le Poudrage Electrostatique des Vegetaux.
Reprint of the proceedings of a conference of La Ligue de Defense Contre les Ennemis des Cultures, Paris, 1947, 19 pp.

Considerable attention is given to the theory of electrostatic dust precipitation, with emphasis on pesticidal dusting.

15. Hebblethwaite, Peter.
The Application of Electrostatic Charging to the Deposition of Insecticides and Fungicides on Plant Surfaces.
Unpublished M.S. thesis. Michigan State University, 1952, 117 numbered leaves.

This thesis deals with the charging of agricultural dusts by an ionized field. A charge was placed on the individual particles by passing them through a negative corona, ionized-field charging-nozzle. The relation of the quantity of dust deposited to the current applied to the nozzle, to the relative humidity, and the temperature and to the distance of the surface being dusted from the nozzle were studied.

16. Johnstone, H. F., and others.
Handbook on Aerosols.
United States Atomic Energy Commission, Washington, D.C., 1950, 147 pp.

Considerable basic material on aerosol behavior is contained in this reference. An extensive bibliography is included. The handbook is obtainable through the U. S. Government Printing Office, Washington 25, D. C.

17. Kunkel, Wulf B.
The Static Electrification of Dust Particles on Dispersion into a Cloud. Journal of Applied Physics 21 (August 1950), pp. 820-832.

This journal article discusses an extensive study of the charge and size distribution of particles in dust clouds of diverse types dispersed in air under a variety of conditions.

18. Kunkel, Wulf B.
Charge Distribution in Coarse Aerosols as a Function of Time.
Journal of Applied Physics 21 (August 1950), pp. 833-837.

This journal article discusses, for air suspensions, the interaction of small particles with normally produced air ions and neutralization of highly charged dust particles.

19. Kunkel, Wulf B., and Hansen, J. W.
A Dust Electricity Analyzer.
The Review of Scientific Instruments 21 (April 1950), pp. 308-314.

This journal article describes in great detail an apparatus by means of which the size and charge of large numbers of microscopic particles can be simultaneously determined.

20. Ladenburg, R.
Untersuchungen uber die physikalischen Vorgange bei der Sogenannten Electrischen Gasreinigung: I Teil: Uber die Maximale Aufladung von Schwebeteilchen.
Annalen der Physik 4 (1930), pp. 863-897.

This journal article, printed in German, gives a thorough development of classical particle-charging theory.

21. Lapple, C. E.
Electrical Precipitators.
Chemical Engineers' Handbook. McGraw-Hill Book Co., New York, 3d. ed., 1950, pp. 1039-1045.

A good discussion is given of particle-charging and precipitation data, with emphasis on industrial precipitators. Some pertinent gaseous electronic data are included. Many references are listed.

22. Loeb, Leonard B.
Static Electrification.
Springer-Verlag, Berlin, 1st. ed., 1958, 240 pp.

This book is a basic work in physics which discusses static electrification theory of interest in particle charging. Although published in Germany, the book is printed in English.

23. Lowe, H. J., and Lucas, D.H.
The Physics of Electrostatic Precipitation. British Journal of Applied Physics, Supplement No. 2: Static Electrification: A Symposium held by the Institute of Physics in London on 25, 26, and 27 March 1953. The Institute of Physics, London, 1953, pp. 40-47.

Particle-charging and precipitation theory, with special reference to power-station precipitators, is presented in some detail.

24. MacLeod, G. F., and Smith, Leslie M.
Deposits of Insecticidal Dust and Diluents on Charged Plates. Journal of Agricultural Research 66 (January 1943), pp. 87-95.

This journal article considers the frictional characteristics of commonly used pesticidal dusts and diluents.

25. Pauthenier, M. M., and Moreau-Hanot.
La Charge des Particules dans un Champ Ionise.
Journal de Physique 3 (December 1932), pp. 590-613.

This article presents, in considerable detail, a classical theory of dust-particle charging in an ionized field. It is written in French.

26. Penney, G. W.
Effects of High-Resistivity Dust in Electrostatic Precipitation.
Electrical Engineering 70 (November 1951), pp. 1009-1013.

A discussion of the reverse-ionization effect in ionized-field particle-chargers is given. A method of measuring the electrical resistivity of dusts is described.

27. Scheffy, W. J.
Bibliography on Aerosols, 1950-1955.
United States Atomic Energy Commission Research Report No. COO-1016. Office of Technical Services, United States Department of Commerce, Washington, D.C., June 1, 1956, 109 pp.

The book consists entirely of a list of references appearing in the above years. References are classified as to subject matter.

28. Splinter, William E.
Deposition of Aerial Suspensions of Pesticides.
Unpublished Ph.D. thesis. Michigan State University, 1955, 164 numbered leaves.

This thesis discusses the influence of particle size on the effectiveness of the insecticide, and the various forces effecting deposition. The effect of gravitational, inertial, and electrical forces on dust of different densities and particle size were studied at 3 relative humidities and 4 wind velocities. The effect of thermo-repulsion, friction charging, and velocity upon deposition were studied.

29. Tilney, R.
Electrostatic Coating Processes. British Journal of Applied Physics, Supplement No. 2: Static Electrification: A Symposium held by the Institute of Physics in London on 25, 26, and 27 March 1953. The Institute of Physics, London, 1953, pp. 51-54.

This paper describes three industrial methods of applying static electricity to the process of liquid coating or painting of parts in production.

30. Yadoff, Oleg.
Un Nouveau Procede de Poudrage Electrique des Vegetaux.
Comptes Rendus, Academie des Sciences, Paris, 222 (March 1946), pp. 544-546.

This article is a relatively brief but informative description of the Yadoff frictional dust-charging process. The work is in French.

31. Yadoff, Oleg.
Sur le Mecanisme d'Electrisation des Grains de Poussiere dans un Jet d'Air Supersonique.
Comptes Rendus, Academie des Sciences, Paris, 222 (November 1946), pp. 588-589.

This short article describes in great detail the dust-charging process within a supersonic air jet. The work is in French.